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NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

OF THE

COLLEGE OF AGRICULTURE AND
MECHANIC ARTS

WEST RALEIGH

PREVENTION OF OAT AND WHEAT SMUT

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N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS

THE NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

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PREVENTION OF OAT AND WHEAT SMUT.

By F. L. Stevens.

Nature and Cause—Smut, Bunt, Black Heads, these are a few of the names under which one of the most common and widespread diseases of cereals is known in this State.

The disease shows itself to the farmer as a black, dusty, or hard mass, usually occupying the place where the grain should be. The mass of dust is really composed of the fruiting bodies, the reproductive parts of the fungus, which are the real cause of the diseased condition. This fungus is a vegetable parasite. It gains entrance to the plants when they are in a susceptible condition of development, this varying with different kinds of plants, grows within the plant as an active parasite, drawing its nourishment during this time from its involuntary host. When the host plant has attained the proper age, and correspondingly, too, the fungus has reached its proper stage of maturity, the disease becomes apparent to the eye as the only too familiar *smut*. Each individual grain of the dusty mass of smut if enlarged sufficiently by magnifying glasses reveals itself as a minute ball of varying size, shape, and marking, according to the particular kind under view.

Smut spores under suitable conditions of moisture, food and heat will sprout and produce smaller spores (*sporidia*) which, if they fall upon the proper host plant in the proper period of its development, will penetrate into it and grow. The host plant may or may not outgrow its enemy. In any event its presence is not apparent to the naked eye until the period of maturity arrives again and another crop of black spores is produced.

Kinds of Smuts—In all there are many kinds of smuts. Something more than two hundred and sixty-eight species are now recorded. About two hundred and five of these are found in the United States growing upon some four hundred and forty-two different kinds of plants[1].

Most smuts are upon unimportant, uncultivated plants. Some of them, such as the *corn* smut, *onion* smut, and the smuts of *wheat, oats, rye, barley,* attack plants of high economic value and cause great damage. The common *corn smut* develops upon almost any part of the corn plant, but is usually most conspicuous upon the ear and tassel. *Onion* smut is in the leaves, often in the bulb. *Rye smut* in the stem; that of *oats, wheat* and *barley* in the ovary, the grain. Another smut of *corn* growing upon the tassel is less widely known.

On *wheat* three kinds of smut are to be recognized; one which

[1] G. P. Clinton, Proc. Boston Soc. Nat. Hist., Vol. 31, No. 9, p. 334, 1904.

shakes out freely from the head, leaving the empty chaff behind; the other two which remain in the chaff as a black, somewhat oily mass where the grain should be. The first mode of behavior has given rise

FIG. 1—Oat Plants, smutted and healthy. Note the short stems of the smutted plant.

to the term *loose smut*. The disagreeable odor pertaining to the two other kinds of wheat smut gives to them the popular name of *stinking smut*. They are also often called *bunt*.

On *oats* there are two kinds of loose smut, but they are so closely alike that only the expert can distinguish between them, and he only by the use of a very powerful microscope.

On *rye* one smut is known, infecting chiefly the leaf sheaths. On cultivated *barley* are two species of loose smut.

PERIOD OF SUSCEPTIBILITY TO INFECTION.

If sporidia fall upon proper parts of the host plant, and at proper age of development of the host plant, infection will follow. If no sporidia are present, or if they fall upon places that are of improper age to be susceptible, or that for other reasons are not susceptible, no infection can occur.

It is evident that to know precisely at what parts and at what periods the various crop plants are open to infection is of utmost importance in looking to the prevention of the disease.

It was early proved that *oats* are susceptible to infection only in very young periods of their development. Kuhn[1] and Wolff[2] held opposing views as to whether it was the young stem or the first leaf sheath that was susceptible. The very exact work of Brefeld[3] settled this point beyond all controversy. Brefeld also proved that corn is susceptible to infections on all young tender growing parts and recently Maddox in Tasmania, Wakagwa in Japan, Brefeld[4] in Germany, have shown that in the case of the *loose smut of wheat* and the *barley smut* infection occurs while the plant is in bloom, this infection affecting the seeds and resulting in smutted plants in the crop raised from such infected seeds.

It is upon these facts that our present modes of prevention are based. The treatment for oat smut is such as to kill the spores adhering to the grain and thus prevent infection during the period of susceptibility, *i. e.,* the very young seedling condition. The same treatment is effective for the stinking smut of wheat. The loose smut of wheat gaining entrance to the embryo in the seed plant before the grain is harvested can not be prevented by such means but can be prevented by the use of the means given below.

Corn being susceptible at all ages of its growth can not be protected by seed treatment, and the only recourse is to cut out and destroy (burn or bury) all the smut possible each year and thereby diminish the number of smut spores floating in the air. The heat of the silo is sufficient to kill corn smut spores, and the silo will undoubtedly be an important factor in lessening the amount of smut in the country.

[1] J. Kuhn, Die Krankheiten der Kulturgewachse. Berlin, 1859.
[2] Wolff, der Brand des Getreides, Halle, Germany. 1874.
[3] Oscar Brefeld, Untersuchungen aus dem Gesammtgebiete der Mykologie. Heft 11, 1895.
[4] Oscar Brefeld and R. Flack, Untersuchungen aus dem Gesammtgebiete der Mykologie Heft 13, 1905; die Bluteninfktion bei den Brandpilzen und die naturliche Verbreitung der Brandkrankheiten.

AMOUNT OF DAMAGE.

The damage caused by smut is usually underrated. In 1884 Arthur[1] in New York by actual count found the oat smut to constitute from 8.5 to 10 per cent of the ordinary crop. In 1886, Plumb[2] by actual count of nearly 11,000 heads determined the amount of smut to be 8.4 per cent; in some fields he found as high as 20, 28, and even 30 per cent. Kellerman and Swingle[3], counting smutted heads in Kansas, found different fields to have 8, 15.3, 18.3 per cent of smut, while single portions of a field had as high as 39 per cent.

AMOUNT OF DAMAGE FROM OAT SMUT IN NORTH CAROLINA.

This disease occurs in all parts of North Carolina where oats are grown. In eighteen counties in the summer of 1908 examination was made for smut, some 65,000 heads of oats being counted. In no field was oat smut absent, and the amount by actual count in several instances was as high as 18, 19 and even 24 per cent.

In one county, with the aid of the local threshers, a conservative estimate was made of the amount of oats raised and of the amount of smut prevailing. From the county clerk the amount of taxes collected was ascertained. It was apparent that the loss from oat smut (a natural tax levied upon those ignorant of the method of preventing smut) slightly more than equalled 10 per cent of the taxes levied by man. How hard does man strive to lower the tax levy! How much does he object to its increase! Yet many a man without resistance allows this equally burdensome and totally unproductive smut tax to be collected yearly without putting forth the trifling effort that is needed to nullify it.

PREVENTIVE MEASURES.

Owing to their great damage and conspicuousness smuts have attracted attention from very early times and many references to them are found in ancient writings. Probably not until 1791, however, was their true nature as vegetable parasites recognized. Many, however, were the means that were suggested for the prevention of these pests; placing laurel branches in the field, change of seed, avoidance of manures, thorough screening, soaking in brine, etc.

Bluestone Treatment—The only one of the early treatments that has proved its value and remained in common use is that of soaking the seed wheat in copper sulphate (bluestone). Tessier, in 1789, after he, in 1786, and Young in 1787, had tested numerous chemicals, seems to have been the first to try this treatment for smut. His test was without results since neither treated nor untreated wheat was smutted that year. It remained for Prevost, of France, in 1807, to

[1] J. C. Arthur, Third Report N. Y. State Station, 1884, p. 382.
[2] C. S. Plumb, Fifth Report N. Y. State Station, 1886, pp, 125 *et seq.*
[3] W. A. Kellerman and W. T. Swingle, Second Report Kan. Exp. Station, 1890, 223.

first publish an account of the successful use of the bluestone for wheat smut. He recommended a solution of about six per cent strength, and the remedy was, and is still, widely used. Various strengths have been employed, one-half per cent being the most highly recommended.

In 1873, Dreisch improved the bluestone treatment by using lime water to follow the bluestone, thus, to a large extent, diminishing the amount of seed killed by the treatment.

The best form of the bluestone treatment (for wheat) is to soak the seed in one-half per cent solution for twelve hours, then for five minutes in milk of lime. This is very effective against the stinking smut of wheat, but does not entirely prevent oat smut[1].

HOT WATER TREATMENT.

Jensen, a Dane, in 1887 and 1888, reported excellent results with oat, barley and wheat smuts from dipping the seed in hot water.

Untreated seed gave 36 per cent of smut.

One-fourth per cent bluestone gave one-half per cent smut.

Warm water, 133° F., 5 min., gave no smut.

The rationale of this treatment is that the smut spores succumb at a temperature of 132° F. for 5 minutes while the grain seed is uninjured by this temperature for 15 minutes.

This method of smut prevention, somewhat modified, has like the bluestone treatment, been very widely employed. It is effective. The only objections to it are its difficulty of manipulation and the great care that is needed to maintain the proper temperature so as surely to kill the smut spores, but as surely to avoid injuring the grain.

FORMALIN TREATMENT.

While the foregoing treatments are good, a still better one is the formalin treatment first introduced in 1897.

Formalin is the commercial name for a 40 per cent solution of formaldehyde in water. Formaldehyde was discovered in 1888. It is made by passing a mixture of air and wood alcohol vapor over heated platinum.

The germicidal value of formalin was first discovered by Trillat in 1888, since which time it has come into prominence as a fungicide. In 1895, Geuther[2] published a paper in which he showed formalin capable of destroying the germinating power of smut spores without injuring the grain.

Formalin was first used and thoroughly tested in America as a preventive for oat smut by Prof. H. L. Bolley, of North Dakota Agricultural Experiment Station, during the three years preceding

[1] W. A. Kellerman and W. T. Swingle, Second Report Kan. Exp. Station, 1890, p. 241.

[2] Th. Geuther Einwirkung von Formaldehyde-losungen auf Getreidebrand. Ber d. deut. Pharm. Gesell., 5, 1895, 328.

1897. In March, 1897, Professor Bolley published his results in bulletin form[1]; Prof. C. P. Close, of New York Station, published a bulletin in December, 1897, presenting the results of some experiments with formalin treatment during that year[2]. During the winter of 1897-98, Prof. M. B. Thomas, of Indiana, read a paper[3], describing experiments concerning the effect of formalin upon the germination of seed oats and suggesting that it might be well to try this substance upon the spores of smut as a possible smut prevention. In 1898, Neger[4] and Tubeuf[5] also published bulletins concerning the relation of formalin to smuts of cereals.

Since the publication of these papers, many Agricultural Experiment Stations have concurred in their recommendations and the use of the formalin treatment has extended to probably every country where oats are grown.

In the various experiments many strengths of formalin have been tested. The strongest solution recommended for use is one pound of formalin to twenty-five gallons of water; the weakest, one pound to one hundred gallons, while by far the greater number of experimenters recommended one pound of formalin to fifty gallons of water.

TREATMENT FOR OAT SMUT AND WHEAT STINKING SMUT.

Two methods of treatment are recommended.

1. A solution is made of one pound of formalin to fifty gallons of water and placed in a barrel or large tub. The seed is then placed in bags and immersed for ten to twenty minutes, or until thoroughly wet, then taken out and dried and stored, or planted immediately. If stored, great care must be exercised not to place the seed where smutted seed has been before or where there is any possibility of smut spores being carried to it. If drilled at once the drill will have to be set to sow more than the usual quantity of seed to the acre to allow for the extra size of the swollen seed.

2. The other method, more easily employed and more to be recommended, consists in sprinkling the seed instead of immersing it. The same strength of solution, that is, one pound to fifty gallons of water, is used.

To treat the grain spread it in thin layer on a smooth barn floor and sprinkle with the diluted formalin, using either a spraying machine or a watering pot. Sprinkle so as thoroughly and evenly to wet the grain with the mixture. Then shovel the grain over thor-

[1] H. L. Bolley, New Studies upon the Smut of Wheat, Oats and Barley, with a resume of treatment experiments for the last three years. (N. Dak. Sta. Bul. 27, 1897, pp. 109–164.)
[2] C. P. Close, Results with Oat Smut in 1897. N. Y. Station Bul. 131, pp. 441-454.
[3] M. B. Thomas, The Effect ef Formalin on Germinating Seeds. (Proc. Ind. Acad. Science, 1897, 144–148).
[4] F. W. Neger, Ueber Desinfekton von Saatgut mittels Formaldehyde-Dampfe. Praktische Blatter fur Pflanzenbau und Pflanzenschutz, Vol. 1, No. 11. November, 1898, pp. 84–85.
[5] Carl von Tubeuf, Scherings Formalingas-Methode. Praktische Blatter fur Pflanzenbau und Pflanzenschutz, Vol. 1, No. 11, November, 1898, pp. 85–86.

oughly a few times to insure even distribution and cover the pile with canvas, carpet, blankets or bagging, to keep the fumes of the formalin within. The pile should stand from 6 to 12 hours in this way. The oats may then be readily dried by mixing with air-slaked lime, and the lime may be removed by the fanning mill. The seed is then ready to sow. It may be stored, but in so doing it is liable to renewed smut infection. The best way is to treat, dry, then sow as soon as practicable.

In general, one gallon of mixture will suffice to treat one bushel of grain. The formalin should be used at the rate of one ounce to three gallons of water.

Formalin is an irritating caustic which should not be brought into contact with the skin in pure form. In diluted condition it is harmless.

Formalin can be purchased from the druggist at a cost of 75 to 95 cents a pound, thus making the cost of treatment not more than 2 cents to the bushel of grain. The gain in increase of yield is estimated at from $1.00 to $5.00 per acre.

EXPERIMENTS CONCERNING INJURY TO SEEDS.[1]

Owing to the many strengths of formalin recommended for the prevention of smut, experiments were undertaken in 1905 to determine what strength is dangerous to the germinating power of the seed. Formalin of the following strengths was used: one ounce to one gallon; one ounce to two gallons; one ounce to three gallons, and one ounce to one-half gallon. The trials showed that the strongest solution quite materially injured the germinating power of the grain, while the other three strengths did not injure the seeds appreciably.

Further experiments were carried out to test the various strengths upon several varieties of oats. It was found that three of the six varieties tested showed much more resistance to the formalin than the other three varieties used.

Tests of the effects of different times of application of the solution were made and it was found that one ounce to one gallon may be used with comparative safety for a period of two hours, and that one ounce to two gallons is dangerous when used for 12 hours.

It was further found that good, heavy, plump seed gave better germination tests after treatment than either average, medium, or poor (light) seed.

WORK IN NORTH CAROLINA.

While the oat crop is not of leading importance in this State, its aggregate is large, amounting to 2,500,000 bushels in 1900. The loss through oat smut is therefore a significant item in State economy.

[1] F. L. Stevens, Thirty-First Report N. C. Station, 1909, p. 30.

Since this disease is so easily prevented and at such trifling cost, every effort has been made to call the attention of the farmers of North Carolina to the loss and methods of preventing it. In 1902, the work was begun by writing to prominent farmers and explaining the treatment to them, sending gratis a sample of formalin sufficient to treat an acre of oats, and a circular giving directions for its use. The distribution of this formalin was further effected by offers made at many farmers' institutes and through various agricultural papers, and through press bulletins published in local papers during the past eight years. Letters were also sent to several hundred school teachers of the State, attempting through them to call attention to the formalin treatment and offering to send free samples to any patron of their schools who would agree to try it and report results.

Many of the farmers who tried the formalin failed to report the results, a few accepted it but for some reason failed to test it. The great majority who received samples tested the treatment and returned to this Experiment Station statements attesting its efficiency and their letters are now here on file. A very few failed to note any beneficial effects owing to the fact that there was little or no smut on the untreated field used for comparison with the treated field.

The efficiency of the formalin treatment has thus been thoroughly demonstrated to the farmers of North Carolina, and many farmers have adopted its use as a permanent practice and the object lessons afforded by these farmers are rapidly leading to a general use of this valuable mode of disease prevention.

WHEAT SMUTS.

As is said on page 76, there are two kinds of smut common on wheat, the *loose smut* and the *stinking smut*.

The *stinking smut* may be prevented by the use of one-half per cent bluestone or formalin. Either treatment is good. The formalin is best. It is employed just as for the prevention of oat smut.

The *loose smut* finds its way into the plant in the very young condition of seed, *i. e.*, before the seed ripens, indeed while the wheat plant is yet in blossom. In the ripe seed the fungus is within the seed itself and is beyond the killing influence of chemical steeps. The bluestone or formalin method employed against the stinking smut of wheat and against oat smut are therefore of no avail. The discovery that infection occurs in the seeds at the time of blooming, however, leads to the suggestion that if one avoids using seed that was exposed to infection during blooming there will be little or no danger from loose smut and conversely if one employs seed that came from a field containing much loose smut such seed is probably infected and will result in a smutted crop.

One remedy against loose smut of wheat is, therefore, when prac-

ticable, to use only seed from fields that were free of loose smut. In many instances such seed can not be obtained. It then becomes necessary to treat infected seed so as to procure from it a sufficient quantity of uninfected seed. This can be accomplished by a modified form of the Jensen hot-water treatment. The directions for procedure drawn from Freeman and Johnson[1] are as follows:

A good, clean, well-cultivated piece of land should be selected for raising seed. The plat should be large enough to provide at least twice as much grain as will be necessary for farm seed the following year in order to allow for loss in cleaning and selecting. This seed plat should not lie near fields of smutted crops of the same cereals, nor should it be so located that the prevailing winds at flowering time can carry spores to the seed plat from a neighboring field of the same grain. This isolation is absolutely necessary. A strip of wood, a corn field, or a large meadow is a valuable protection.

After seed for the plat has been cleaned by the best fanning and sifting, it must be treated by the Jensen method. The clean seed should be soaked for from five to seven hours in water at ordinary

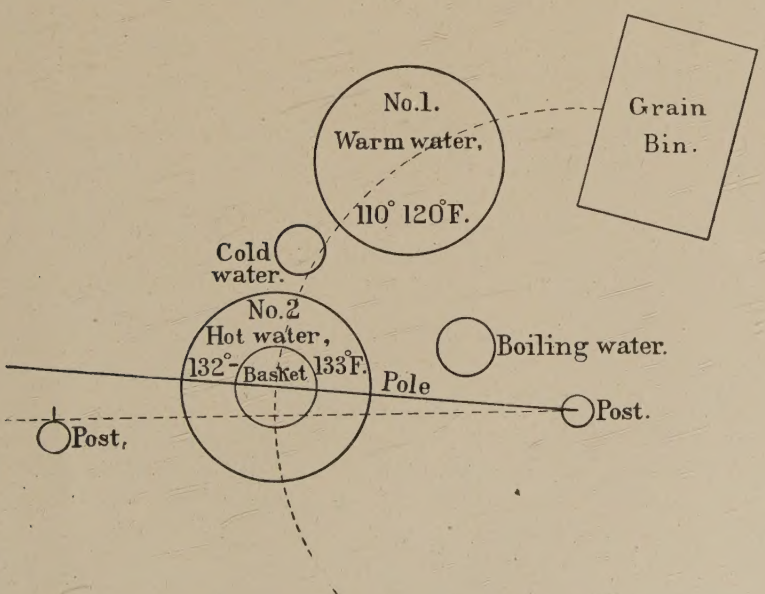

FIG. 2.—Diagram showing arrangement for treating smutted seed.

room temperature, 17° to 22° C. (63° to 72° F.), then placed in small, loose sacks or wire baskets, containing not more than one-half peck each, and drained for a short time. The seed must be treated in

[1] E. M. Freeman and E. C. Johnson, U. S. Dept. Agr. Bur. Plant Indus., 152, July 12, 1909.

small lots in order that all of the grain may quickly and uniformly reach the desired temperature. Two tubs or vats of water should be provided. In one tub (No. 2) the exact temperature required should be maintained. The other tub (No. 1) is used for bringing the grain to the temperature in tub No. 2. Galvanized iron tubs of 20 to 40 gallons' capacity, and kerosene or gasoline double-burner stoves are convenient.

The drained sacks or baskets of seed should be plunged into tub No. 1 for a minute, then transferred to tub No. 2, and kept agitated while immersed at temperatures and for the periods specified below, the temperatures mentioned being maintained as nearly as possible: For barley, 15 minutes at 52° C. (125.6° F.). For wheat, 10 minutes at 54° C. (129.2° F.). In treating barley, if the temperature should rise above 52° C. (125.6° F.), the time of immersion must be reduced to ten minutes at 53° C. (127.4° F.), or five minutes at 54° C. (129.2° F.). Above 54° C. (129.2° F.) there is no safe margin. If the temperature falls slightly below 52° C. (125.6° F.), the time of treatment should be increased in proportion. A temperature lower than 51° C. (123.8° F.) is not effective. In treating wheat, if the temperature should rise above 54° C. (129.2° F.) or fall below 52° C. (125.6° F.), the time for immersion must be diminished or increased accordingly. Under no circumstances should a temperature of more than 55° C. (131° F.) be allowed. Temperatures below 51° C. (123.8° F.) are ineffective. A reliable thermometer is necessary, since the use of an inaccurate instrument may result in injury to the germinating power of the grain or in failure to prevent the smut.

The men working together can easily treat one bushel of grain an hour, or enough seed in one day to sow a seed plat of from 6 to 10 acres. The seed may be dried by spreading it out in thin layers not over 2 ins. in depth on a clean granary floor or on canvas, and shoveling or raking it from time to time. It should not be allowed to sprout. Care must be taken to prevent freezing of the grain when it is moist, as this will impair germination.

Seed treated as indicated may be planted as soon as it is sufficiently dry to run freely through the drills, making allowance for the swollen seed. Before sowing the seed should be tested for germinating power, and a corresponding increase in the rate of seeding be made.

The seed plat may be maintained from year to year, or as long as any smut is present in the grain fields. Seed obtained from the treated seed plat does not have to be treated the following year.